CHAPTER 3

3 AFFECTED ENVIRONMENT

To determine whether the various component options would have a substantial effect on the human environment, an accurate understanding of the environment as it exists before the project is developed is necessary. This chapter describes, on a resource-by-resource basis, the existing environment that would be affected if the project proceeds.

FGMI, and its predecessors, have conducted environmental baseline analyses for many resources in the True North Mine area. The information contained in this chapter is drawn from those analyses, which are referenced appropriately and available for review, and from other relevant literature. Because of the juxtaposition of the True North and Fort Knox mines, much of the baseline analyses done for the Fort Knox NEPA and permitting processes is relevant also to these same True North processes. Thus, FGMI's Fort Knox Mine EA (FGMI, 1993) and associated studies are referenced frequently below.

Unlike mining projects located in remote areas with no human development nearby, the True North prospect has a past mining history and is adjacent to some active nonmining human activities and development.

3.1 GEOLOGY AND PHYSIOGRAPHY

3.1.1 REGIONAL GEOLOGY

The True North deposit is located within the Yukon-Tanana Terrane, which is bounded on the northeast by the Tintina Fault and on the southwest by the Denali Fault. The Yukon-Tanana Terrane consists of accreted metamorphic rocks of primarily sedimentary origin that were subjected to greenschist, amphibolite, and eclogite-facies grade metamorphism. Intermediate to felsic plutons and stocks intruded the metamorphic rocks during the Cretaceous Period (85 – 95 million years ago) (FGMI, 1993).

The Yukon-Tanana metamorphic rocks, within the Fairbanks Mining District, are primarily composed of the Chatanika Terrane and the Fairbanks Schist. The Chatanika Terrane is postulated to have been thrust over the Fairbanks Schist prior to retrograde metamorphism of both units to greenschist facies and the Cretaceous intrusive activity. High angle northeast striking faults transect the district and offset all rock types (FGMI, 1993). For a more detailed discussion of regional geology see WMCI (2000).

3.1.2 TRUE NORTH DEPOSIT GEOLOGY

The True North property is bisected by the high angle northeast striking Eldorado Fault that emplaced the Fairbanks Schist, in a high angle contact with the allochthonous Chatanika Terrane. The True North deposit occurs in a structurally complex mineralized zone within the Chatanika Terrane, parallel to the Eldorado Fault. Ore zones are typically gently dipping, variably brecciated zones that may be related to regional thrust faulting. The thickness and shape of the breccia zones are widely variable and appear to have been modified by higher angle faults (FGMI, 2000a).

Calcareous and carbonate-altered schist of the Chatanika Terrane hosts the True North deposit. These rocks have been subdivided into three main lithologic subunits: (1) a slate unit consisting of slate and fine-grained carbonaceous quartzite; (2) a mafic schist unit consisting of chlorite-biotite-amphibole schist, eclogite, amphibolite, and marble; and (3) a felsic unit consisting of muscovite schist, quartz-muscovite-biotite schist, and quartzite. The felsic and mafic schist units are the main hosts for gold at True North (FGMI, 2000a).

Fine-grained gold is closely associated with pyrite, arsenopyrite, and (less directly) stibnite in the unoxided portion of the True North deposit. Gold occurs in drusy quartz veins and altered and brecciated schist adjacent to the quartz veins. The most intensely mineralized zones are graphitic breccias with numerous quartz–carbonate-sulfide veins. Less intensely mineralized zones contain fewer quartz veins in variably brecciated, iron carbonate and calcium carbonate altered schist. Weakly mineralized to unmineralized zones are calcite-altered and are locally brecciated (FGMI, 2000a).

The True North ore body is elongated northeast gently dipping to the southwest. The estimated reserves for the True North Hindenburg and East pits are 7.4 million tons, averaging 0.063 oz/t. For a more detailed description of the deposit's geology see WMCI (2000).

3.1.3 PHYSIOGRAPHY

Topography of the project area consists of rounded, even-topped ridges with gentle slopes (Fig. 1.2-2). Ridge-crest altitudes range from 1,500 to 2,600 feet on Pedro Dome and rise 500 to 1,500 feet above valley floors (Haugen et al., 1982). Hillsides in the project area frequently are characterized by slopes of 10 to 30 percent, and approach 50 percent on the northwest flank of Pedro Dome.

Drainage patterns of the project area watersheds are dendritic. South and southwest of the deposit drainage is into Murray Creek, a tributary of Dome Creek. On the west and northeast of the deposit drainage is into Spruce Creek, and Whiskey Gulch and Louis Creek, respectively, all tributaries of Little Eldorado Creek to the north.

3.2 SOILS AND PERMAFROST

3.2.1 SOILS

Soils in the project area vary according to their position in the landscape and the occurrence of permafrost. Two broad geographic landform types exist, mountain slope and floodplain.

The poorly drained soils in the valley bottoms and on the northern exposures of the project area usually are underlain by discontinuous permafrost. Mountain slope soils have developed in loess. Accumulation of loess is more prevalent on gently climbing toe slopes with southerly exposures than on steeper northerly exposures. The loess cap is generally thicker in the toe slope position than on the ridge tops (FGMI, 1993).

Soils on floodplains have developed in sandy or silty alluvium. This material has a mixed origin, which includes loess from distant glacial sources and bedrock materials from adjacent uplands. In general, near stream channels, soils are sandy in texture and the permafrost is deep or absent. Farther from the stream channel, soils become progressively more silty in texture and permafrost is closer to the surface (FGMI, 1993).

On the mountain sides, permafrost occurs on the north-facing slopes of ridges and in the sloping valleys along secondary drainages. Large areas of soil on floodplains also can be underlain by permafrost. If the insulating moss layer or litter is removed on permafrost soils, the overlying soil may subside. In summer, soils with shallow permafrost typically are saturated to near the mineral soil surface. Frost heaves and differential soil subsidence following surface disturbance are hazards (FGMI, 1993).

Overall, the soil mantle in the project area is shallow, with bedrock or weathered bedrock usually present within 50 cm of the soil surface. Upland soils found in broadleaf forest and shrub communities are characterized by relatively thin organic layers (2-14 cm) over a silt loam or sandy-silt loam. Charcoal fragments are common in the upper mineral soil horizon; drainage generally is moderate to good. Upland black spruce communities are found on soils distinctly different from other upland vegetation types (Roth and Kidd, 1996).

All sites ground truthed by Roth and Kidd (1996) and classified as wetland had soils that were saturated. Soil pits dug at the base of drainages rapidly filled with water. At higher elevations water either seeped from the walls of the pits or could be shaken readily from the soil matrix. No histosols, i.e., organic horizons ≥ 40 cm, were recorded in sample pits, but organic horizons ranged from 8 to 33 cm. Mineral soils were silt or silt loam, with large coarse fragments and mottling. Drainage ranged from imperfect to very poor, and low chroma matrices were typical.

Further descriptions of soils in the project area may be found in Kidd and Rossow (1996), Kidd and Pullman (1997), Pullman and Kidd (1998).

3.2.2 PERMAFROST

3.2.2.1. REGIONAL CONDITIONS

The International Permafrost Association (IPA, 1998) defines permafrost as "ground (soil or rock and the included ice and organic matter) that remains at or below 0°C for at least two consecutive years". Therefore, permafrost is characterized by measurement of subsurface temperatures (WMCI, 2000).

Permafrost in the project area is discontinuously distributed, and thus the interaction between permafrost and shallow groundwater is complex. Groundwater may occur above, below, and adjacent to frozen subsurface zones, as wells as within (or penetrating through) the permafrost itself. The presence of permafrost can control the movement of groundwater because of its impermeability. In a discontinuous permafrost environment, permafrost may be present or absent due to a variety of factors, including human and natural disturbances of the terrain and vegetation, local climate variations, and general aspect of the area (i.e., north facing slopes) (WMCI, 2000).

Permafrost exists at various depths throughout the Fairbanks area (Lawson, et. al, 1996). The top of the permafrost ranges from approximately 2 ft to over 50 ft deep. The thickest thawed zones generally occur beneath swales or former stream channels, roads, buried pipelines, building and building excavations, and other areas where vegetation has been cleared. The bottom surface of the permafrost generally ranges from 30 ft to over 160 ft deep. Areas of minimum permafrost thickness occur in areas adjacent to non-permafrost zones while maximum thickness occurs generally in low-lying areas with south facing aspects. The top and bottom surfaces of the permafrost can have highly irregular relief (WMCI, 2000).

Characterization of the three-dimensional distribution of permafrost is difficult and complex. Transitions from unfrozen to frozen zones can be abrupt with little or no surface expression. Vegetative zones are generally heavily influenced by permafrost because the presence of frozen ground can restrict drainage and helps to maintain cool soil temperatures. Low soil temperatures, in turn, slow the breakdown of organic materials and help establish conditions that create and maintain wetland communities (Newmont, 1997).

In general, the presence of permafrost can be inferred from a variety of wetland vegetative types, including dwarf black spruce woodland and black spruce scrub. Upland vegetative types, including closed broadleaf or closed mixed forest types, are often indicative of the absence of permafrost (WMCI, 2000).

3.2.2.2. SITE CONDITIONS

Surface vegetation and wetland areas -- A variety of studies in the Fairbanks area has shown that general correlations can be made between surface vegetation and wetland types and the presence of permafrost (Lawson, et. al, 1996; Jorgenson, et. al., 1999; Golder, 2000). In general, the presence of permafrost results in restricted drainage and cool soil temperatures, while the absence of permafrost can result in well-drained conditions. The resulting variations in vegetation and wetlands ecosystems can be used to assess the potential presence of permafrost.

The following general relationships apply for the correlation of permafrost and vegetative types (Lawson, et. al., 1996):

Upland vegetative zones, such as closed or open broadleaf (consisting primarily of birch and aspen) or closed mixed forest (mixed broadleaf and larger needleleaf varieties [consisting of white spruce and large black spruce]) are associated with well drained conditions and are indicative of the absence of permafrost or deep thaw depths.

Various lowland vegetative zones, including wetlands consisting of dwarf black spruce woodland and shrub, are associated with poor drainage and are indicative of the presence of permafrost.

Riverine vegetative zones that are associated with larger flood plains and rivers generally indicate the absence of permafrost. Groundwater is thought to discharge primarily within these areas.

Wetlands in the vicinity of the mine site are discussed in detail in Section 3.9 (Wetlands). Figure 3.9-1 in that section presents a map of wetland vegetation types on the True North mining claims. The upland vegetative zone is present over large areas of the ridge top and along south facing slopes, makes up approximately 60 percent of the immediate site area. Permafrost is likely absent throughout these areas. Lowland vegetative types, including dwarf black spruce forest and scrub areas, are present along north facing slopes and within the primary drainages. These zones are likely underlain by permafrost of various thicknesses and thaw depths. There are no riverine vegetative zones in the immediate project area (WMCI, 2000).

Impact of permafrost on groundwater flow -- The presence of permafrost has an impact on both shallow and deep groundwater flow. At the True North site, shallow groundwater is generally isolated to areally limited thaw zones above the permafrost. Significant shallow flows were encountered in a single location during exploration drilling. Flows of around 1 gpm were noted at depths of 25 to 30 ft. The flows were likely a result recent infiltration from snowmelt and spring rains in the vicinity of the boring. A review of all geologic borings in the vicinity indicated that shallow flow was encountered in one other boring. None of the other borings within 300 ft encountered shallow flows. The depths to first water ranged from 120 to more than 280 ft in these borings. This suggests that the shallow flow observed is likely representative of an isolated, areally limited flow zone perched on top of permafrost in this area (WMCI, 2000).

The main groundwater flow system at True North is deeper, occurring at depths ranging from 120 to over 300 ft deep. This system occurs below permafrost in areas underlain by permafrost, and at depth in areas where permafrost is absent (WMCI, 2000).

3.3 Geotechnical and Seismic Considerations

Although Fairbanks does not lie directly on any of the identified major fault systems, it does have several east-west trending fault systems passing near it, including the Denali. A list of known major statewide earthquakes from 1786 to 1970 shows 19 of 222 earthquakes, or almost 9 percent of the total, occurred in the immediate Fairbanks area (Hays, 1980).

The historical record shows seismic events measured to Mercalli Intensity VIII (approximately Richter magnitude 6 to 6.5) in the Fairbanks area, and a substantial concentration of Intensity VII to IX (Richter magnitude 5.5 to 6.7) events occurred in interior Alaska (Hays, 1980). This trend is evident in the 1971-to-1980 time frame as well, with a marked concentration of Intensity V and VI events having occurred in the immediate project vicinity.

The 1997 Uniform Building Code (UBC) places the project site firmly in Seismic Zone 3, a high-risk zone (UBC, 1997). The 1990 Minimum Design Loads for Buildings and Other Structures (American National Standards Institute [ANSI] AS 8.51), now known as ASCE 7-88, generalized the boundaries, but still places Fairbanks well into Zone 3 (America North, Inc., 1991b).

3.4 Climate

3.4.1 Temperature

The climatic conditions of the Fairbanks area are characterized by typical interior Alaskan conditions, with short warm summers and long cold winters. Diurnal temperature fluctuations can be very large and are driven by the vast change of sunlight occurring throughout the year. The area receives about 18 to 21 hours of sunlight per day during June and July, and only 4 to 10 hours of sunlight per day during November through March. The Fairbanks Weather Service Office reports that systematic differences exist between recorded temperatures in Fairbanks and in the mountains to the north and east of town. The regions to the north and east of Fairbanks are cooler during the summer and warmer during the winter. For the region, December and January are the coldest months while temperatures reach their annual peaks in July. Summer temperature fluctuations are comparatively low, ranging between 30° and 90°F, while winter temperatures fluctuate between –65° and 45°F (WMCI, 2000).

Table 3.4-1 summarizes monthly average temperatures for the climatological stations reviewed for the baseline study. Data from the Fort Knox Mine are only available for the period between 1990 and 1994. The Ridge Station at the mine is likely most similar to conditions at True North. Based on these records, the average annual temperature near the project area was 32.3°F. These temperatures are slightly warmer than the regional long-term average at other nearby stations, but represent only a few years of data (WMCI, 2000).

Review of the climatic data available indicate that the Gilmore Creek Station, with its proximity to the project area, similar elevation, and 37-year period of record is likely most representative of longer-term climatic conditions at the True North project area. The yearly average temperature at the Gilmore Creek Station is 25.3°F. A summary of the average monthly temperatures adopted for the True North project is included in Table 3.4-1 (WMCI, 2000).

3.4.2 PRECIPITATION

Precipitation in the Fairbanks area is affected by two distinct physiographic regions: the Tanana Flats to the south and the Yukon-Tanana Uplands to the north. Annual precipitation in the Tanana Flats area is approximately 10 inches per year, whereas the total in the uplands area is approximately 20 inches per year (America North, 1992). Higher precipitation in the uplands is due to orographic effects, stronger summer storms, and higher overall snowfall rates. The True North site is located within the upland area and would be expected to have higher overall precipitation rates than the Fairbanks area (WMCI, 2000).

Table 3.4-1

Summary of regional mean monthly temperatures (°F)

Station	Period of record	Longitude (ddd-mm)	Latitude (dd-mm)	Elevation (ft-msl)	Month												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Fairbanks WSO (#502968)	1961-	147-52	64-49	440	-10.1	-3.6	11.0	30.7	48.6	59.8	62.5	56.8	45.5	25.1	2.7	-6.5	26.9
College Univ. (#509641)	1961-	147-52	64-51	480	-7.0	-0.8	14.1	30.8	47.7	58.4	61.2	56.1	45.1	25.4	4.0	-4.6	27.5
College Observatory (#502107)	1961-	147-50	64-52	620	-6.1	-0.7	13.2	30.1	47.4	58.3	61.0	55.8	44.6	24.8	4.4	-3.5	27.4
Gilmore Creek (#503275)	1962-	147-31	64-59	970	-9.4	0.8	10.9	28.5	43.9	54.5	57.3	52.9	42.5	22.0	4.6	-4.9	25.3
Chena Hot Springs (#501574)	1962-	146-03	65-03	1200	-13.7	-3.3	8.3	25.2	41.4	53.2	55.8	51.2	41.0	20.4	0.3	-6.7	22.8
Fort Knox Mine (Ridge station)	1992-			1955	4.5	8.0	17.5	34.0	48.0	55.5	60.3	53.3	35.7	24.5	14.3	9.5	32.3
Fort Knox Mine (Valley station)	1990-			1386	5.0	0.8	13.6	29.2	48.2	56.7	58.7	52.4	35.5	19.0	5.8	0.7	29.5
True North Project (Newmont station)	1995-			~1500	-0.9	18.8	14.8	30.4	47.8	61.9	62.7	51.6	47.8	20.5	13.9	2.0	30.9
Regional average					-4.7	2.5	12.9	29.9	46.6	57.3	59.9	53.8	42.2	22.7	6.3	-1.8	27.8
Adopted Baseline Temperature					-9.4	0.8	10.9	28.5	43.9	54.5	57.3	52.9	42.5	22.0	4.6	-4.9	25.3
Site Average					2.9	9.2	15.3	31.2	48.0	58.0	60.6	52.4	39.7	21.3	11.3	4.1	30.9

A summary of precipitation data from nearby stations is presented in Table 3.4-2. Based on these data, the regional average annual precipitation is approximately 12.9 inches. However, as noted above, the uplands area of the True North project area will generally experience higher annual precipitation totals. As shown in Table 3.4-2, only a short period of record is available at stations similar in location and elevation (i.e. Fort Knox Mine and True North stations). However, review of these data during months with overlapping records indicates that precipitation at each of these stations is similar to that recorded at the Gilmore Creek station (WMCI, 2000).

Because of its period of record (37 years), the Gilmore Creek station most likely represents the long-term precipitation trends at the True North project area. Based on the Gilmore Creek data, the majority (approximately 60 percent) of the precipitation in the project area occurs during the summer and early fall between the months of June and September. The maximum monthly precipitation occurs in July (averaging 3.0 inches) and the minimum monthly precipitation occurs in March (averaging 0.3 inches). The long-term average annual precipitation at the Gilmore Creek station is 14.6 inches per year. This value may be somewhat low for the project area, based on the expected 20 inches a year for upland areas. A summary of the average monthly precipitation adopted for the True North project is included in Table 3.4-2 (WMCI, 2000).

3.4.3 EVAPORATION

Significant evaporation occurs only during the summer months due to low values of solar radiation during the winter months. Evaporation data gathered from the College University Experiment Station are the only record of evaporation in the True North project vicinity. Pan evaporation records are available but are missing several days of measurement.

Table 3.4-3 shows a summary of the mean pan evaporation for each month. Average annual evaporation is approximately 18 inches per year, all occurring between June and September. The maximum evaporation occurs during June, averaging 5.04 inches per month (WMCI, 2000).

3.5 SURFACE WATER HYDROLOGY

WMCI (2000) described the surface water hydrology of the project area, which lies within the drainage area of the Chatanika River. The northern area of the site drains to Little Eldorado Creek and includes the tributaries of Last Chance Creek, Louis Creek, Discontented Pup, Whiskey Gulch, and Spruce Creek (Fig. 1.2-2). The southern area drains into Dome Creek, primarily via the tributary of Murray Creek. Table 3.5-1 shows the drainage area and average slope for each channel. The South Fork of Spruce Creek and Upper Louis Creek recorded low flows of less than 0.001 cfs and were deemed ephemeral streams. Lower Spruce Creek, Whiskey Gulch, and Murray Creek approached base flow conditions and are expected to be perennial streams. The hydrographs showed several spiked readings caused by large precipitation events, and recorded flows as high as 1.4 cfs in Lower Spruce Creek in September of 1995.

Table 3.4-2

Summary of regional monthly mean precipitation (inches)

Station	Period of record	Long (ddd-mm)	Lat (dd-mm)	Elev (ft-msl)	Month												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Fairbanks WSO Airport (#502968)	1961-1990	147-52	64-49	440	0.5	0.4	0.4	0.3	0.6	1.4	1.9	2.0	1.0	0.9	0.8	0.9	10.9
College Univ. Experiment (#509641)	1961-1990	147-52	64-51	480	0.5	0.4	0.4	0.3	0.6	1.6	2.2	2.3	1.1	0.9	1.5	0.9	12.7
College Observatory (#502107)	1961-1990	147-50	64-52	620	0.5	0.5	0.4	0.3	0.6	1.6	2.1	2.3	1.1	1.0	0.9	0.9	12.1
Gilmore Creek (#503275)	1962-1999	147-31	64-59	970	0.4	0.3	0.3	0.5	1.0	1.9	3.0	2.9	1.5	1.0	1.0	0.9	14.6
Chena Hot Springs (#501574)	1962-1978	146-03	65-03	1200	0.5	0.4	0.7	0.5	0.7	2.1	2.7	3.1	1.2	0.9	0.8	0.8	14.4
Fort Knox Gold Mine (Admin. Station)	1997-1999				0.5	0.4	0.5	0.5	0.8	2.0	2.8	3.0	1.4	1.0	0.9	0.9	14.5
True North Project Area (Newmont Station)	1995-1998			~1500	0.3	0.6	0.4	0.2	0.3	1.5	1.7	2.9	1.1	1.1	0.4	0.4	11.0
Regional average					0.4	0.4	0.5	0.4	0.6	1.7	2.3	2.6	1.2	1.0	0.9	0.8	12.9
Adopted Baseline Precipitation					0.4	0.3	0.3	0.5	1.0	1.9	3.0	2.9	1.5	1.0	1.0	0.9	14.6

Table 3.4-3
Summary of regional mean pan evaporation rates (inches)

Station	Period of record	Long (ddd-mm)	Lat (dd-mm)	Elev (ft-msl)	Month												
					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
College Univ. Experiment (#509641)	1931-99	147-52	64-51	480	0.00	0.00	0.00	0.00	4.25	5.04	4.56	2.82	1.38	0.00	0.00	0.00	18.05

Table 3.5-1
Summary of watershed characteristics for True North project area creeks

Channels 2nd Order	**1st Order**	**Drainage Area (acres)**	**Length (ft)**	**Upper Elev (ft)**	**Lower Elev (ft)**	**Average Slope (ft/ft)**
Eldorado Creek		4875	12375	855	645	0.0170
	Marshall Gulch	555	11220	1740	760	0.0873
	Whiskey Gulch	244	2640	1120	810	0.1174
	Discontented Pup	110	7260	1280	815	0.0640
	Louis Creek	691	4290	1080	855	0.0524
	Last Chance Ck	1891	10560	1940	855	0.1027
	Spruce Creek	1924	11880	1020	640	0.0320
Dome Creek		7967	35223	1739	574	0.0326
	Murray Creek	584	5280	1080	820	0.0492

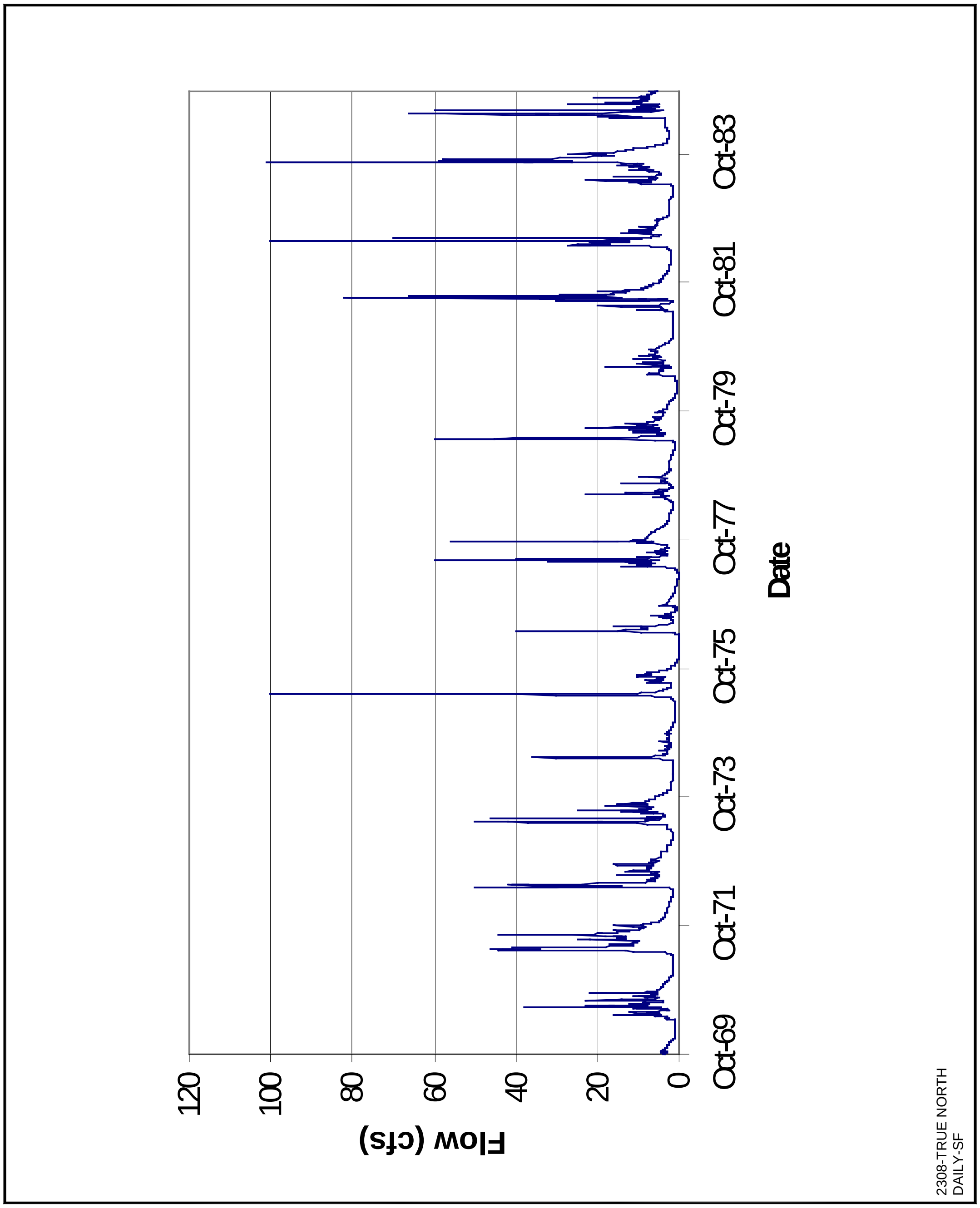
There are five USGS gauging stations within a 25-mile radius of the project area: Caribou Creek near Chatanika (#15535000), Little Chena River near Fairbanks (#15511000), Chena River at Fairbanks (#15514000), Poker Creek near Chatanika (#15534900), and Chena River near Two Rivers (#15493000). The gauging stations are all part of the Tolovana River and Chena River Basins.

Caribou Creek has similar characteristics to the Little Eldorado Creek including slope, drainage area, and riparian zone**.** Figure 3.5-1 is a hydrograph of the historical daily streamflows at the Caribou Creek gauging station. The Caribou Creek drainage represents a good analog of potential flow conditions in the Little

Eldorado Creek and Dome Creek drainages near the True North site (Halepaska, 1992). Water balance data collected at the Fort Knox Mine confirm that Caribou Creek characteristics can be used as a reasonable representation of flow conditions in areas local to the True North project area.

WATER
MANAGEMENT
CONSULTANTS

Figure 3.5-1 Historical daily streamflows at Caribou Creek



3.6 GROUNDWATER HYDROLOGY

3.6.1 REGIONAL GROUNDWATER CONDITIONS

Regional groundwater flow is heavily influenced by the presence of permafrost. Because of its low permeability, permafrost has a large impact on groundwater flow in terms of potentially restricting lateral flow, and focusing recharge and discharge zones in areas where permafrost is absent. Key components of regional groundwater flow in a discontinuous permafrost environment include:

Groundwater flow above the permafrost (suprapermafrost groundwater) is likely highly localized and discontinuous.

Groundwater flow below the permafrost (subpermafrost groundwater) represents the primary regional flow system and may occur under both unconfined and confined conditions.

Recharge to deep groundwater occurs through zones where permafrost is absent over extensive areas (such as south facing slopes or hilltops) or taliks (unfrozen zones in permafrost areas).

Recharge to the regional groundwater flow system is primarily sourced by snowmelt during the late spring. Recharge potential during the summer is generally low due to relatively high soil moisture storage potential during the primary evaporation season, and the fact that summer rainfall in the Fairbanks area is generally of low intensity and short duration. Enhanced infiltration could occur during very wet summer rainfall events.

Discharge of deep groundwater likely occurs primarily along stream courses or in lakes that penetrate the permafrost. Discharge can also occur as springs or seeps within drainages and along hill slopes where permafrost is discontinuous (WMCI, 2000).

These key components of regional groundwater flow are summarized on a conceptual cross-section, shown in Figure 3.6-1 (after Kane, 1981).

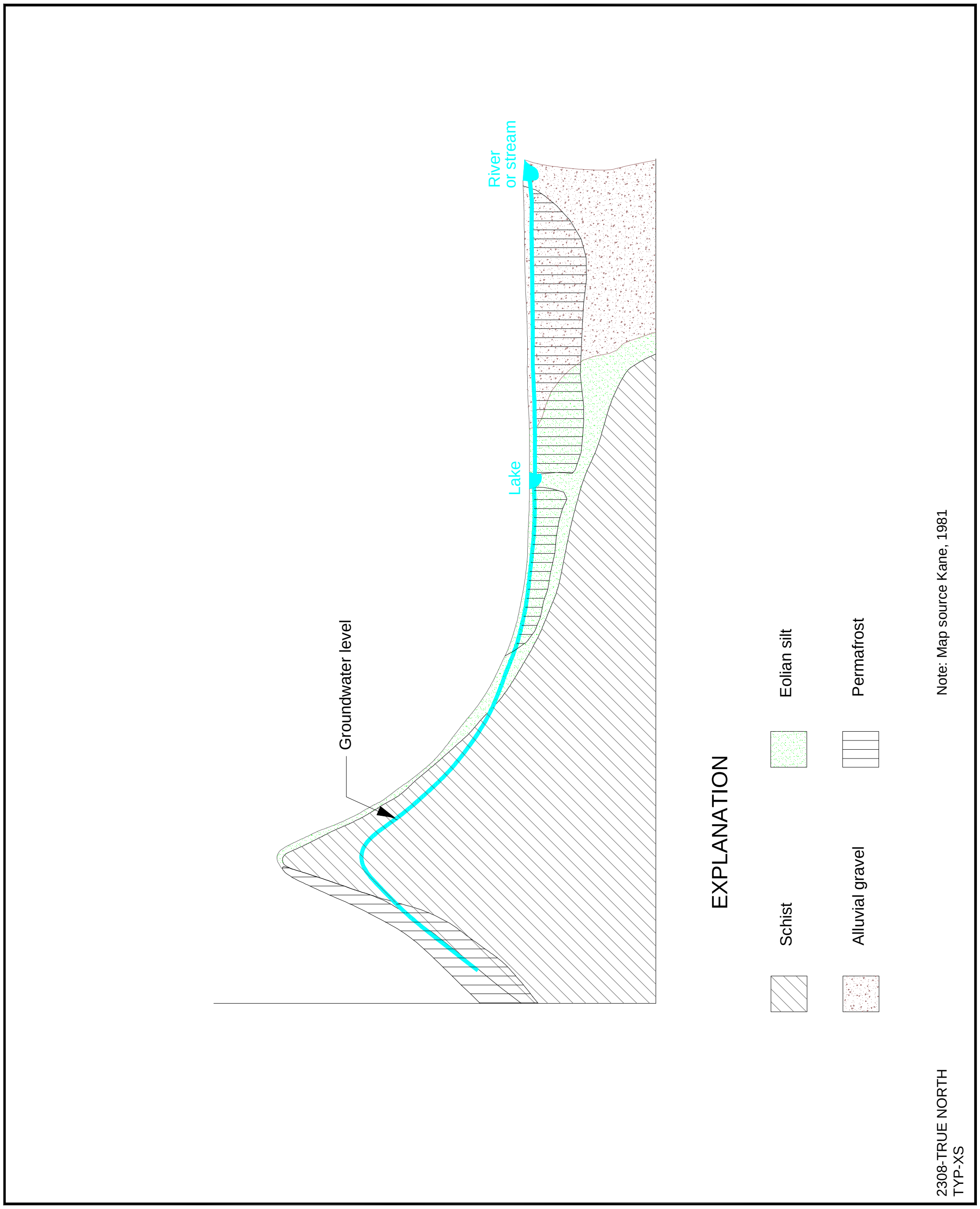
3.6.2 Mine Area Groundwater Conditions

Data on long-term fluctuations in groundwater elevation within the main flow system at the site are available from two piezometers installed by Newmont, TN-182 and TN-281. Monthly water level measurements from these piezometers were collected from November 1994 through November 1998, and are shown on Figure 3.6-2. TN-281 is located along the ridge line between the Dome Creek and Little Eldorado Creek drainages, in a zone of upland vegetation where permafrost is interpreted to be absent. Water levels in this piezometer show a general decline between 1994 and 1998 from a maximum elevation of 1,626 ft to 1,564 ft above mean sea level (amsl), with the piezometer drying out in May 1998. A general seasonal trend in water levels is noted in this piezometer, with water levels rising during the late summer/early fall period, and then declining during the remainder of the year. This seasonal fluctuation included water fluctuations of up to 35 ft during 1995, with a longer term decline of approximately 62 ft between October 1995 and May 1998 (WMCI, 2000).

Piezometer TN-182 is located on a hill slope above Murry Creek, and is in an area with lowland vegetation that is likely underlain by permafrost. Water levels in this piezometer had much smaller fluctuations, but with generally the same trends as observed in TN-281. Water levels in TN-182 declined from a maximum of 1,123 ft amsl during 1995 to a low of 1,117 ft amsl in November 1998. Minor seasonal fluctuations are evident in the water levels, with a slight rise in water levels during summer 1995, followed by a long-term decline (WMCI, 2000).

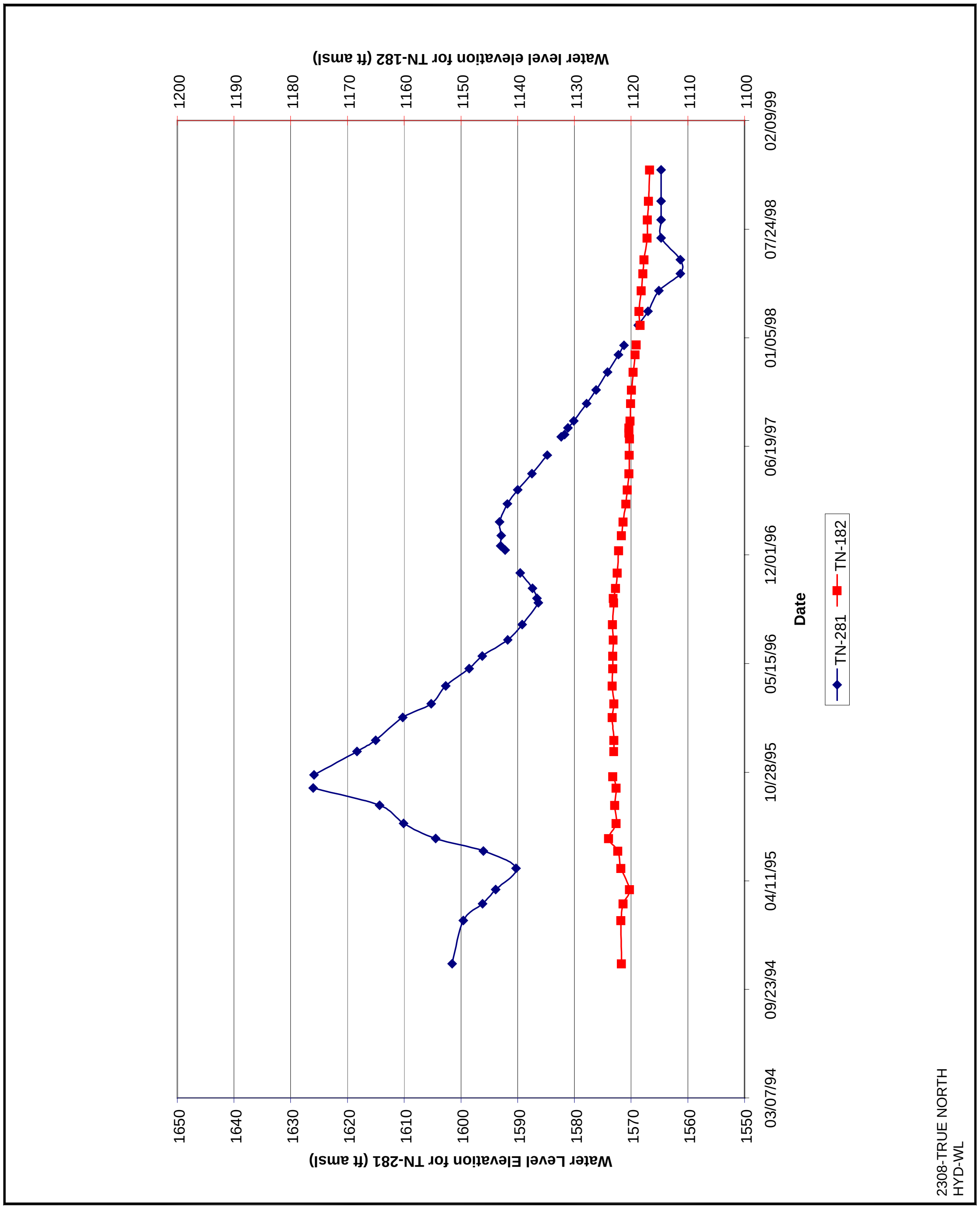
WATER MANAGEMENT CONSULTANTS

Figure 3.6-1 Conceptual cross section of permafrost conditions and groundwater flow



WATER MANAGEMENT CONSULTANTS

Figure 3.6-2 Hydrograph showing historic water levels in TN-182 and TN-281



Based on a review of available long-term water level data, the following conclusions can be made:

Water levels in TN-281 are representative of a relatively low permeability fractured-rock system. The magnitude of the water level changes, suggest active recharge to a fracture system through unfrozen rock material. The seasonal infiltration of water fills discrete fracture zones, resulting in the observed large increase in water level in the piezometer. The fractures then slowly drain as groundwater discharges into downgradient stream areas.

Water levels in TN-182 are representative of groundwater flow isolated below permafrost that does not receive direct seasonal recharge. Water levels below permafrost do not fluctuate significantly, but do follow the general system trends.

The long-term decline in water levels noted in both wells is likely due to dryer than average conditions noted for the area during the 1994 – 1998 period.

Water levels from the nine newly installed monitoring wells have been collected monthly since December 1999. Water within three of the monitoring wells froze shortly after installation (MW-1, MW-4, and MW-5), likely due to permafrost or frozen ground surrounding the wells. Water levels in all of the other 7 monitoring wells showed a general decrease between January and June 2000. Water level declines ranged from less that 1 ft in MW-9 to almost 5 ft in MW-8. Monthly monitoring of water levels is ongoing such that seasonal trends can be observed and characterized (WMCI, 2000).

Based on these piezometric data, groundwater is interpreted to flow to the north, northeast, and northwest off the divide between the Dome Creek drainage and the Little Eldorado Creek drainages. Groundwater is interpreted to discharge within the creek beds based on the observed shallow depths to water in these areas (WMCI, 2000).

Hydraulic gradients across the site vary from approximately 0.04 ft/ft near Louis Creek to 0.2 ft/ft near the divide. The relatively high hydraulic gradients in the divide area are representative of a low permeability fractured-rock flow system. In the area of the Hindenburg Pit, groundwater flows northward at an average gradient of approximately 0.10 ft/ft. Under the proposed East Pit, groundwater flows to the northeast at an average gradient of approximately 0.13 ft/ft (WMCI, 2000).

3.6.3 GROUNDWATER SYSTEM PHYSICAL CHARACTERISTICS

Groundwater at the True North site generally flows within fractured bedrock in areas of higher elevations into shallow alluvial material associated with creeks and streams. Preliminary estimates of hydraulic conductivity for the system were developed based on slug tests performed in two of the monitoring wells (WMCI, 2000). The slug tests were analyzed using the method of Bower and Rice (Kruseman and DeRidder, 1990) for unconfined wells. A summary of hydraulic conductivity estimates from the two slug tests is presented in Table 3.6-1.

Table 3.6-1
Summary of hydraulic conductivity estimates

Monitoring well	Estimated hydraulic conductivity (ft/min)	Estimated hydraulic conductivity (ft/day)	Estimated hydraulic conductivity (cm/sec)
MW-02	1.7×10^{-4}	0.25	8.8×10^{-5}
MW-07	1.1×10^{-4}	0.16	5.8×10^{-5}
Geometric mean	1.4×10^{-4}	0.20	7.1×10^{-5}

The hydraulic conductivity estimates from the two tests were similar, with a geometric mean estimate of 0.20 ft/day (7.1×10^{-5} cm/sec). The geometric mean is considered the best estimate of larger-scale hydraulic conductivity because it is assumed to vary over a log-normal distribution. The hydraulic conductivity estimates from the tests are in the range expected for fractured bedrock (WMCI, 2000).

The storage properties of the groundwater system can not be estimated directly from slug test results. However, based on work at similar sites and estimates provided in the literature (Dominico and Schwartz, 1990), it is estimated that the drainable porosity of the fractured rock ranges from less than 0.01 to 0.05. The specific yield of alluvial material near the creeks likely ranges from 0.10 to 0.30 (WMCI, 2000).

3.6.4 CONCEPTUAL MODEL OF GROUNDWATER FLOW IN THE TRUE NORTH AREA

Recharge -- Recharge to site groundwater likely occurs primarily within areas where permafrost is absent. These areas are likely associated with the broadleaf upland vegetation. At the site, these areas occur primarily along the ridge top and on south facing slopes. Recharge through the upland zone is supported by the relatively large seasonal water level fluctuations observed in TN-281. The majority of recharge likely occurs during late spring and early summer, when snowmelt is occurring, and to a lesser degree during late summer rainfall. Little to no recharge is thought to occur through the permafrost (WMCI, 2000).

Discharge -- Groundwater flows from higher elevations along the divide to lower elevations along the nearby creeks (Murry Creek, Spruce Creek, and Louis Creek). While some stretches along the creeks are underlain by permafrost, there are likely zones were permafrost is absent or taliks occur. Groundwater discharges within these zones, providing base flow to the creeks. This is supported by late summer stream flow measurements within the creeks (WMCI, 2000).